***Appendix A: Teacher Resources***

***Teacher Notes***

***Minds On:***

*\*\* After watching the video clip, review key points regarding Mendel’s biography. Refer to both the video clip and the article that students had read for homework (Appendix B). Ensure*

Key points:

* + Gregor Mendel (1822-1884) was an Augustinian monk that documented scientific observations of inheritance in plants.
  + He received proper recognition in the early 1900’s after other scientists made similar observations.
  + He is now known as the “Father of Genetics”, and his laws can be applied to other sexually reproducing organisms, including humans.
  + Mendel grew pea plants and through his observation and cross fertilization of these plants he discovered that certain traits were inherited in specific patterns.
  + He was able to cross plants with specific traits by transferring pollen from the stamen of one plant to the stigma of another. In this manner he could observe and record the traits of the offspring from a specific cross.
  + Even before heredity rules were discovered people were using artificial selection on plants and animals for their own uses.
  + Although many where breeding animals and plants for desirable traits, they weren’t able to predict which traits on the animals would disappear and reappear throughout the generations.
  + In order to have more control over what traits would be transmitted to the offspring scientists had decided that 3 essential questions had to be answered.

1) What is inherited?

2) How is it inherited?

3) What is the role of chance in heredity?

* Before Mendel began his experiments, the general public had 2 misconceptions about inheritance:

1) That one parents contributes most to an offspring inherited features.

2) Blended inheritance: parental traits become mixed and forever changed in the offspring.

***Consolidation:***

*\*Review the questions for each article. The answers are found bellow.Students will be asked to discuss their answers with the rest of the class.*

Article 1 Answers:

1. **Why did Mendel study pea plants?**

A: Because they are available in many varieties which allows him to study different characteristics. He was able to control the mating process of the plants (because both female and male organs are in the plant).

1. **What method did Mendel use to cross-fertilize pea plants?**

A: Mendel dusted pollen from another plant onto the carpel of another plant.

Article 2 Answers:

1. **Why was Mendel sure to use “purebred” strains of pea plants to begin his experiments?**

A: Because when purebred plants self-pollinate all of the offspring have the same variety. By hybridizing two varieties, by looking at the offspring, Mendel will be able to see which variety was inherited.

1. **What are the 7 purebred characteristics that Mendel studied when cross-fertilizing pea plants?**

A: Flower color, Flower position, Seed color, Seed shape, Pod shape, Pod color and Stem length.

Article 3 Answers:

1. **What did Mendel observe in the F1 generation when he cross-pollinated two different pure-line characteristics?**

A: All of the offspring had only inherited one of the parents’ characteristics. The other characteristic was not apparent in any of the offspring.

1. **What is a dominant trait?**

A: A trait (allele) that is fully expressed. (heterozygote)

1. **What is a recessive trait?**

A: A trait (allele) that is not expressed. (heterozygote)

1. **What trait is normally seen in the F1 generation? What does this tell us about the blended model of inheritance?**

A: Only the dominant trait is seen in the F1 generation. If the blended theory of inheritance had been true, the offspring would had had a blend of both parental traits. For example, when Mendel cross the white plant with the purple plant, if the blended theory were true one would expect to see light purple plants. But that was not the case.

Article 4 Answers:

1. **For each self-pollination of F1 generation what was the approximate ratio observed?**

A: 3: 1 (3 = dominant, 1= recessive)

1. **In the first experiment, the characteristic of seed shape was studied. What he found was 5474 round seeds and 1850 wrinkled seeds.**

**What does this information tell us about the recessive trait?**

A: The recessive trait reappeared in the F2 generation, thus in the F1 the recessive trait did no disappear it was simply masked by the dominant trait. In the F1 plant, there may have been heterozygote (a plant with both the dominant and the recessive gene) present, but only the dominant gene was expressed. When a heterozygote plant was self-pollinated some offspring were created that only contained recessive genes.

*(this may require further explanation)*

*\*\*After answering all of the questions, present the main 4 concepts that Mendel uncovered from his experiments. Write all of the concepts on a chart paper and hang it on the board. Remind students to write these concepts in their notebook.*

**4 main concepts:**

1. Alternative versions of genes account for variations in inherited characteristics.

Explain gene and allele: Characteristic = gene, trait= allele

1. For each character, an organism inherits two alleles, one from each parent. Thus, an individual will inherit two alleles of the same gene.

3) If the two alleles differ, the dominant allele, determines the organism’s appearance. The recessive allele is masked and is not noticeable.

4) Law of Segregation: 2 alleles for a heritable character separate during gamete formation and end up in different gametes.

***Appendix B: Student Resources***

**Mendel’s Articles**

*Instructions:*

With your group members read each article and answer the questions bellow. You will have 10 minutes to read each article and complete the questions. At the end of the 10 minutes, you will present your answers to the class through a discussion.

*About the articles:*

The following articles where written by Gregor Mendel and translated to the English language. The articles contain information regarding the methods used to conduct his pea plant experiments as well as the results for the study. Within the articles Gregor Mendel also discusses the trends he observed in the experiment and explains their significance.

For your better understanding only certain sections of the articles were included within this document.

The articles were retrieved from the following website: http://www.mendelweb.org/Mendel.html

**Article 1: Selection of the Experimental Plants**

The selection of the plant group which shall serve for experiments of this kind must be made with all possible care if it be desired to avoid from the outset every risk of questionable results.

The experimental plants must necessarily:

Possess constant differentiating [characteristics](http://www.mendelweb.org/MWgloss.html#characters)

1. The [hybrids](http://www.mendelweb.org/MWgloss.html#hybrid) of such plants must, during the flowering period, be protected from the influence of all foreign [pollen](http://www.mendelweb.org/MWgloss.html#pollen), or be easily capable of such protection.
2. The hybrids and their offspring should suffer no marked disturbance in their [fertility](http://www.mendelweb.org/MWgloss.html#fertile) in the successive [generations](http://www.mendelweb.org/MWgloss.html#generation).
3. At the very outset special attention was devoted to the [Leguminosae](http://www.mendelweb.org/MWgloss.html#leguminosae) on account of their peculiar floral structure. Experiments which were made with several members of this [family](http://www.mendelweb.org/MWgloss.html#family) led to the result that the [genus](http://www.mendelweb.org/MWgloss.html#genus) [Pisum](http://www.mendelweb.org/MWgloss.html#pisum) was found to possess the necessary qualifications.

Some thoroughly distinct forms of this genus possess characters which are constant, and easily and certainly recognizable, and when their hybrids are mutually [crossed](http://www.mendelweb.org/MWgloss.html#cross) they yield perfectly [fertile](http://www.mendelweb.org/MWgloss.html#fertile) progeny.

This circumstance is especially important. As additional advantages worth mentioning, there may be cited the easy culture of these plants in the open ground and in pots, and also their relatively short period of growth. [Artificial fertilization](http://www.mendelweb.org/MWgloss.html#artfert) is certainly a somewhat [elaborate](http://www.mendelweb.org/MWgloss.html#elaborate) process, but nearly always succeeds. For this purpose the bud is opened before it is perfectly developed, the [keel](http://www.mendelweb.org/MWgloss.html#keel) is removed, and each [stamen](http://www.mendelweb.org/MWgloss.html#stamen) carefully extracted by means of [forceps](http://www.mendelweb.org/MWgloss.html#forceps), after which the stigma can at once be dusted over with the foreign pollen.

***Questions:***

1. Why did Mendel study pea plants? What made them a good organism to study?
2. What method did Mendel use to cross-fertilize pea plants

***Article 2***

*Background information:*

When conducting his study, Mendel chose to study plants that were pure line. A pure line of true-breeding is when a population breeds true for a particular trait. For instance, when a pure-line green pea self-fertilizes, all of its off spring will be green and possess the green seed characteristic.

Mendel chose to only study characteristics that were true-line and did not have an intermediate form. For instance, he looked at flower color, because it was either purple or white. He did not look at seed weight, because this could vary along a continuum.

These specific traits are now known to be “genes”.

***Division and Arrangement of the Experiments***

“If two plants which differ constantly in one or several [characters](http://www.mendelweb.org/MWgloss.html#characters) be [crossed](http://www.mendelweb.org/MWgloss.html#cross), numerous [experiments](http://www.mendelweb.org/MWgloss.html#experiment) have demonstrated that the common characters are transmitted unchanged to the [hybrids](http://www.mendelweb.org/MWgloss.html#hybrid) and their progeny; but each pair of [differentiating characters](http://www.mendelweb.org/MWgloss.html#differentiating), on the other hand, unite in the hybrid to form a new character, which in the progeny of the hybrid is usually variable. The object of the experiment was to observe these variations in the case of each pair of differentiating characters, and to [deduce](http://www.mendelweb.org/MWgloss.html#deduce) the law according to which they appear in successive [generations](http://www.mendelweb.org/MWgloss.html#generation). The experiment resolves itself therefore into just as many separate experiments are there are constantly differentiating characters presented in the experimental plants.

The characters which were selected for experiment relate:

1. To the difference in the form of the ripe seeds. These are either round or roundish, the depressions, if any, occur on the surface, being always only shallow; or they are irregularly angular and deeply wrinkled (P. quadratum).
2. To the difference in the color of the seed [albumen](http://www.mendelweb.org/MWgloss.html#albumen) (endosperm). The albumen of the ripe seeds is either pale yellow, bright yellow and orange colored, or it possesses a more or less intense green tint. This difference of color is easily seen in the seeds as their coats are transparent.
3. To the difference in the color of the seed-coat. This is either white, with which character white flowers are [constantly correlated](http://www.mendelweb.org/MWgloss.html#constcor); or it is gray, gray-brown, leather-brown, with or without violet spotting, in which case the color of the standards is violet, that of the wings purple, and the stem in the [axils](http://www.mendelweb.org/MWgloss.html#axil) of the leaves is of a reddish tint. The gray seed-coats become dark brown in boiling water.
4. To the difference in the form of the ripe pods. These are either simply inflated, not contracted in places; or they are deeply [constricted](http://www.mendelweb.org/MWgloss.html#constrict) between the seeds and more or less wrinkled (P. saccharatum).
5. To the difference in the color of the unripe pods. They are either light to dark green, or vividly yellow, in which coloring the stalks, leaf-veins, and [calyx](http://www.mendelweb.org/MWgloss.html#calyx) participate.\*
6. To the difference in the position of the flowers. They are either [axial](http://www.mendelweb.org/MWgloss.html#axial), that is, distributed along the main stem; or they are terminal, that is, bunched at the top of the stem and arranged almost in a false umbel; in this case the upper part of the stem is more or less widened in section (P. umbellatum).
7. To the difference in the length of the stem. The length of the stem is very various in some forms; it is, however, a constant character for each, in so far that healthy plants, grown in the same soil, are only subject to unimportant variations in this character. In experiments with this character, in order to be able to discriminate with certainty, the long [axis](http://www.mendelweb.org/MWgloss.html#axis) of 6 to 7 ft. was always [crossed](http://www.mendelweb.org/MWgloss.html#cross) with the short one of 3/4 ft. to 1 [and] 1/2 ft.”

***Questions:***

1. Why was Mendel sure to use “purebred” strains of pea plants to begin his experiments?
2. What are the 7 purebred characteristics that Mendel studied when cross-fertilizing pea plants?

***Article 3***

*Background information:*

Mendel observed that certain traits in pea plants, such as seed color and shape, flower color and plant height, were inherited in specific patterns from parent to offspring. He cross-pollinated pure plants with different traits and studied the resulting offspring. The crossing of two true-breeding characteristics is known as hybridization.

The true-breeding parents are known as the “parental generation” (P generation), and their offspring are known as the F1 generation.

The following Article describes the results that were observed after the hybridization of a gene between two different peas.

***The Forms of the*** [***Hybrids***](http://www.mendelweb.org/MWgloss.html#hybrid)

[Experiments](http://www.mendelweb.org/MWgloss.html#experiment) which in previous years were made with ornamental plants have already affording evidence that the hybrids, as a rule, are not exactly intermediate between the parental species.In some cases, however, one of the two parental characters is so preponderant that it is difficult, or quite impossible, to detect the other in the hybrid.

This is precisely the case with the Pea hybrids. In the case of each of the 7 [crosses](http://www.mendelweb.org/MWgloss.html#cross) the hybrid-character resembles that of one of the parental forms so closely that the other either escapes observation completely or cannot be detected with certainty. Henceforth in this paper those characters which are transmitted entire, or almost unchanged in the [hybridization](http://www.mendelweb.org/MWgloss.html#hybridization), and therefore in themselves constitute the characters of the hybrid, are termed the [dominant](http://www.mendelweb.org/MWgloss.html#dominant), and those which become latent in the process recessive. The expression "recessive" has been chosen because the characters thereby designated withdraw or entirely disappear in the hybrids, but nevertheless reappear unchanged in their progeny, as will be demonstrated later on.

Of the [differentiating characters](http://www.mendelweb.org/MWgloss.html#differentiating) which were used in the [experiments](http://www.mendelweb.org/MWgloss.html#experiment) the following are [dominant](http://www.mendelweb.org/MWgloss.html#dominant):

1. The round or roundish form of the seed with or without shallow depressions.
2. The yellow coloring of the seed albumen.
3. The gray, gray-brown, or leather brown color of the seed-coat, in [association](http://www.mendelweb.org/MWgloss.html#association) with violet-red blossoms and reddish spots in the leaf [axils](http://www.mendelweb.org/MWgloss.html#axil).
4. The simply inflated form of the pod.
5. The green coloring of the unripe pod in association with the same color of the stems, the leaf-veins and the [calyx](http://www.mendelweb.org/MWgloss.html#calyx).
6. The distribution of the flowers along the stem.
7. The greater length of stem.

***Questions:***

1. What did Mendel observe in the F1 generation when he cross-pollinated two different pure-line characteristics?
2. What is a dominant trait?
3. What is a recessive trait?
4. What trait is normally seen in the F1 generation? What does this tell us about the blended model of inheritance?

***Article 4***

*Background information:*

After observing only one of the traits in the F1 offspring, Mendel self-pollinated the F1 generation and observed the results. The trait that was not apparent in the first generation had reappeared in the second generation.

Mendel concluded that the strait had not disappeared in the first generation, but was hidden by the other trait factor. This explained the law of dominance.

***The First*** [***Generation***](http://www.mendelweb.org/MWgloss.html#generation) ***From the*** [***Hybrids***](http://www.mendelweb.org/MWgloss.html#hybrid)

In this generation there reappear, together with the [dominant](http://www.mendelweb.org/MWgloss.html#dominant) [characters](http://www.mendelweb.org/MWgloss.html#characters), also the recessive ones with their peculiarities fully developed, and this occurs in the definitely expressed [average](http://www.mendelweb.org/MWgloss.html#average) proportion of 3:1, so that among each 4 plants of this generation 3 display the dominant character and one the recessive. This relates without exception to all the characters which were investigated in the [experiments](http://www.mendelweb.org/MWgloss.html#experiment). The angular wrinkled form of the seed, the green color of the [albumen](http://www.mendelweb.org/MWgloss.html#albumen), the white color of the seed-coats and the flowers, the [constriction](http://www.mendelweb.org/MWgloss.html#constrict) of the pods, the yellow color of the unripe pod, of the stalk, of the [calyx](http://www.mendelweb.org/MWgloss.html#calyx), and of the leaf venation, the umbel-like form of the inflorescence, and the dwarfed stem, all reappear in the numerical proportion given, without any [essential](http://www.mendelweb.org/MWgloss.html#essential) alteration. Transitional forms were not observed in any experiment.

Expt. 1: Form of seed. From 253 hybrids 7324 seeds were obtained in the second trial year. Among them were 5474 round or roundish ones and 1850 angular wrinkled ones. Therefrom the ratio 2.96:1 is [deduced](http://www.mendelweb.org/MWgloss.html#deduce).

Expt. 2: Color of albumen.. 258 plants yielded 8023 seeds, 6022 yellow, and 2001 green; their ratio, therefore, is as 3.01:1.

Expt. 3: Color of the seed-coats. Among 929 plants, 705 bore violet-red flowers and gray-brown seed-coats; 224 had white flowers and white seed-coats, giving the proportion 3.15:1.

Expt. 4: Form of pods. Of 1181 plants, 882 had them simply inflated, and in 299 they were constricted. Resulting ratio, 2.95:1.

Expt. 5: Color of the unripe pods. The number of trial plants was 580, of which 428 had green pods and 152 yellow ones. Consequently these stand in the ratio of 2.82:1.

Expt. 6: Position of flowers. Among 858 cases 651 had inflorescences [axial](http://www.mendelweb.org/MWgloss.html#axial) and 207 terminal. Ratio, 3.14:1.

Expt. 7: Length of stem. Out of 1064 plants, in 787 cases the stem was long, and in 277 short. Hence a mutual ratio of 2.84:1.

If now the results of the whole of the experiments be brought together, there is found, as between the number of forms with the dominant and recessive characters, an average ratio of 2.98:1, or 3:1. The dominant character can have here a double signification; namely, that of either a parental character or a hybrid-character. In which of the two significations it appears in each separate case can only be decided in the following generation. As a parental character it must pass over unchanged to the whole of the offspring; as a hybrid-character, on the other hand, it must maintain the same behavior as in the first generation.

***Questions:***

1. For each self-pollination of F1 generation what was the approximate ratio observed?
2. In the first experiment, the characteristic of seed shape was studied. What he found was 5474 round seeds and 1850 wrinkled seeds.

What does this information tell us about the recessive trait.

***Homework Questions***

1. How did Mendel determine that the offspring of a parent population where not due to blended inheritance?
2. What did Mendel conclude in the second experiment when he self-pollinated the F1 generation?
3. Fill in the blanks of the following sentence:

Pea color is controlled by one \_\_\_\_\_\_\_\_\_\_, which has a “green” form and a “yellow” form.

Each form is called a(n) \_\_\_\_\_\_\_\_\_\_\_\_\_\_.

1. According to Mendel’s model, what do the offspring inherit from the parent generation?
2. When Mendel first studied peas he concluded that each trait is controlled by a factor that has two different versions. There are now terms used to describe these concepts. Describe and explain what these terms are.
3. What is meant by true-breeding or pure line? Why did Mendel only use true-breeding plants?
4. What is the difference between the P, F1 and F2 generations?
5. In the articles Mendel determined which characteristics where dominant and recessive. According to the law of dominance, what would you expect from the following crosses.

|  |  |
| --- | --- |
| ***Hybridization*** | ***F1 generation*** |
| Inflated x Constricted |  |
| Yellow seed x Green seed |  |
| Tall x Dwarf |  |
| Axial flower x Terminal flower |  |
| Purple flower x White flower |  |
| Round seed x Wrinkled seed |  |
| Green pod x Yellow pod |  |